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Many regard the selection of floor coatings as an uncomplicated process. One can simply go to the nearest big box store and ask for a recommendation or just pick up what looks like it will work. Others realize there is more to the coating selection process and therefore develop specifications—some good, some not so good. Weak specs often result when key steps in the selection process are overlooked.

This article discusses the key steps that should be taken while developing the protocol for a concrete flooring project. Within these steps are criteria that need to be addressed by one or all parties involved with the job. Some of these criteria may include substrate degradation, moisture within the substrate, surface preparation, application considerations, and chemical resistance and physical properties of the flooring material. Additionally, standardized references should play a role throughout the entire job process. Finally, case histories of differing applications are presented and discussed. This article gives an overview of the subject, not a comprehensive discussion.

Selecting Flooring for Concrete:

An Overview of What Not to Overlook

Background

Many times the difference between a successful floor-lining project (i.e., one with a good service life) and an unsuccessful one (that fails prematurely) can be reduced to five steps. The following steps are instrumental in the development and completion of the floor-coating project.

- Pre-project inspections of existing facilities
- Specification development
- Development of an appropriate floor coating selection process
- Selection of a qualified and well-trained applicator
- Establishment of and adherence to an appropriate quality control /quality assurance (QC/QA) process, including technical service from the lining system manufacturer

Each step will be discussed briefly.

Pre-project Inspections of Existing Facilities

All parties associated with the project should inspect the facility before the project begins. All of the parties—design engineers, architects, contractors, and a representative of the lining manufacturer—are stakeholders in the project and must exhibit the required commitment to its success. Their inspection of the site is a beneficial first step to understanding the scope and magnitude of what is required for a successful project.

The areas to be lined should be examined for abnormalities such as obvious surface defects and areas of contamination. Failed linings that may still be in place can be looked at closely and potential problem areas can be noted. Particular attention should be paid to evidence of moisture or ground water infiltration. Detailed questions can be asked of the operators regarding these aforementioned items and others. Information pertaining to the exposure conditions for the lining system, such as exposure frequencies, spill procedures, and general cleanup methods, should be obtained. All parties should also develop an overall view of the work to be performed.

Specification Development Is Critical

A poorly written specification, or, equally bad, an inappropriate specification, can doom the project to a premature failure before the first craftsman appears on the site. The specification development process must take into consideration the substrate along with its condition and history. The quality and age of the concrete are vital factors to address. Potential problems such as ground water and substrate settlement or movement (including excessive vibration) must also be examined.

Additionally, choosing an inappropriate reference standard or a test method, such as an ASTM test method, for a given material can preclude a successful installation. The mechanical properties of the material used not only have to be project specific, but must also have appropriate limits set for the expected physical forces. For example, specifying 20,000-psi compressive strength for a 45-mil coating on a floor subjected to significant thermal changes and abrasion, but not subject to a compressive load is inappropriate. The appropriate properties to evaluate for this example are coefficients of thermal expansion of the floor and the lining materials, flexural strength, flexural modulus of elasticity (MOE), tensile strength, bond strength, and abrasion resistance. In fact, a high compressive strength may be indicative of a material that is too rigid to perform as required.

The specification must include not only material requirements, but requirements on the abilities and training of all applicators. It must also delineate the required inspections, inspection points, test methodologies to be used, and pass/fail criteria of those tests.

Floor Coating Selection Process

The selection process may involve more than the specifier alone choosing material. It may not be possible for the specifier to determine the suitability of a given material based upon published chemical resistance data or from anecdotal claims. ASTM test methods and standards for chemical resistance of these materials do not specify pass/fail criteria. One manufacturer may interpret the results very conservatively and cautiously; however, another may be less conservative. The best recommendation may well be difficult to discern.

The specifier needs to not only ask for the above types of information, but also request the case histories of previous projects where similar exposures or application conditions existed. A reputable manufacturer or applicator will provide this information.

Sometimes, however, you will be, as the old saying goes, "The first to eat the oyster." That is, periodically the product that appears to be best suited has no relevant track record or it is so new that is has no track record at all. This situation is where the selection process must require verification of all relevant properties. The lining manufacturer should provide the data, their pass/fail limits, and the test methods used. Finally, the selection process must ensure that the test methods used are those prescribed by ASTM and other authorities for those material types. For example, do not allow plastic test methods for a coating and do not use steel substrate test methods for the evaluation of a concrete substrate.

Selecting a Contractor

This step is frequently the determinant in the degree of success obtained with the overall project. A great contractor may not be able to make the wrong product work and conversely, a poorly trained and unqualified applicator may have success-threatening problems even if the correct material is selected.

It is crucial to examine the history of the contractor firm and its applicators. Ideally, the contractor/applicators would have 15 to 20 years of experience in general flooring application experience and five or more years of application experience with the specified type of flooring. Additional qualifications might include SSPC-QP 8, "Standard Procedure for Evaluating the Qualifications of Contracting Firms That Install Polymer Coatings or Surfacings on Concrete and Other Cementitious Surfaces," and a letter of certification by the material manufacturer.

Quality Control/Quality Assurance (QC/QA) Process

The QC/QA process involves more than a program to inspect and/or test materials installed. The QC/QA program must cover substrate inspection and testing where necessary or required, as well as the surface preparation. The QC/QA process also ensures that the applicator stores, mixes, and applies the materials in accordance with the manufacturer's instructions. The applicators must

Selection, Application, and Performance

One of the nation's leading cereal suppliers had a 150,000-squarefoot food processing facility in dire need of repair. The facility's floor was approximately 10 years old and was suffering from the effects of heavy-duty forklift traffic as well as daily cleaning with aggressive chemicals. The concrete was spalled and cracks were evident throughout the facility. Because this area manufactured foods for human consumption, the floor needed to meet the requirements imposed by the U.S. Government's Food and Drug Administration (FDA).

Beyond meeting FDA requirements, the need for long-term performance was paramount; $10,000 worth of product is produced per hour so shutdown is extremely costly. The facility dedicated a small team of managers to explore the product offerings of the largest flooring manufacturers in North America. They looked at multiple resins systems, including urethane mortars and epoxy flooring systems. After a critical analysis, a 100% solids hybrid epoxy lining was selected for its physical strength, chemical resistance, and the quality reputation of the manufacturer.

Surface Preparation (first of two passes) Photos courtesy of the authors

Application by hand trowel

The facility selected a qualified contractor, and together, the facility representative and contractor, along with the lining manufacturer, developed a protocol to minimize the impact on the plant by applying the flooring system in three distinct phases. Because the hybrid epoxy system is 100% solids, the contamination impact on existing lines was limited and the impact on the production of the facility was minimal.

The existing coating on the concrete was removed by shot blasting, and the edges were treated with small hand grinders utilizing cup stones and diamond grinders. The concrete was prepared in accordance with

demonstrate the required competency to properly install the protective system specified. This certification and qualifications usually require an onsite demonstration with appropriate QC testing of the applied system. The QC/QA process should involve technical service provided by the lining manufacturer (as specified) and direct communication among the manufacturer, the applicator, and project management. Final inspection should occur with a physical walkthrough by all interested parties for final acceptance.

Case Histories

Case histories often provide important information for all parties and should be required submittals in the pre-bid process. The case histories should be examined for relevance to the project at hand, application conditions and methods, ease of installation, performance, maintenance requirements, service life, costs, and owner satisfaction. Examples of some of the kinds of information that case histories can provide are reflected in the cases on pp. 36–37 (below) and p. 40.

Flooring Systems

Floors are exposed to just about everything handled or produced at any given facility. Whatever comes into the facility or is made in the facility will probably come into contact with the floors at some point, by accident or otherwise. Process area floors and secondary containment floors often are subject to the most aggressive exposures, especially chemicals. Several types of floor lining systems can be used to protect concrete. Some of the most common types are described briefly below.

Organic Systems

Thin- and thick-film organic systems are the most commonly used materials for protecting floors. The available chemistries include bis A epoxies, bis F epoxies, novolak epoxies, polyesters, bis A vinyl esters, novalak vinyl esters and polyurethanes. (Inorganic alkali silicates, calcium aluminates and furans do not make good candidates for thin film linings.) Organic linings are typically applied at thicknesses ranging from a few mils to one inch and are bonded to the concrete either by direct bond or a primer. The systems can be formulated into trowelable toppings, sprayable linings, pour and spreads, or even for brush or roller application. The organic systems above offer ease of use, low permeance, excellent chemical resistance and, depending upon the thickness and the particular formula-

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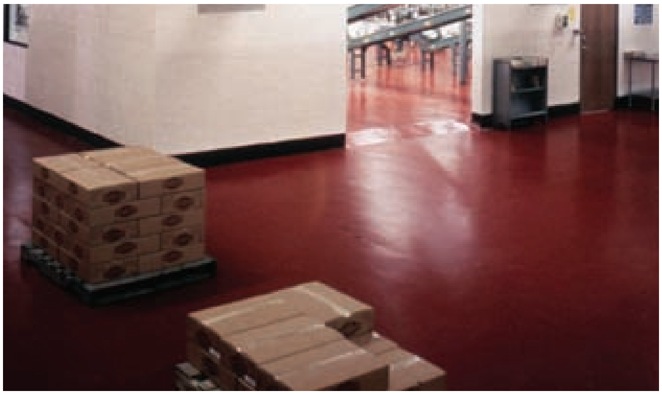
History of a Floor Coating in a Food Plant



Finished Floor (Red)

SSPC-SP 12, and received a surface profile similar to a CSP-6 as described in the International Concrete Repair Institute, Guideline # 3732.

A 100%-solids penetrating primer was applied with a rubber squeegee and back-rolled with a short mohair roller to ensure complete wet-out of the concrete substrate. The areas subjected to heavy forklift abuse in conjunction with the organic acids received a one-quarter-inch-thick overlay of a hybrid novolac epoxy system, which was applied by hand and power troweling. The finely blended aggregate within the floor topping system was intended to provide exceptionally consistent compaction, which would result in superior abrasion and impact resistance. The proprietary mix of rounded and angular constituents provided a surface that exceeds OSHA's slip resistance requirements (coefficient of friction) while preserving the system's ease of cleanliness.

Finished Floor (Grey)

The flooring systems were recently inspected after their 15th year, and although the system has lost its gloss, and areas subject to UV rays have faded a bit, the flooring system is fully functional, and the customer continues to be very pleased.

tion, good to excellent physical abuse protection as well.

Masonry

Masonry brick and masonry flooring systems have been used for centuries. When combined with 21st century technology, the systems provide excellent long-term durability in a number of physical and chemically demanding environments. This flooring type utilizes brick or tile and a setting-bed, grout, and/or mortar material to bond the masonry unit and floor. Both the masonry unit and setting material are chosen specifically for the chemical environment of the job.

Several types of brick are commonly used, such as Type I, II, and III acid-resistant brick and carbon brick. These brick materials must conform to the physical requirements of ASTM C279: *Standard Specification for Chemical Resistant Masonry Units*. The differences among Type I, II and III acid-proof brick are their chemical resistance and degree of absorption, though all three are made from clay, shale, or mixtures of the two. Type II and III brick are used mostly for acids, whereas carbon brick is employed when hydroxides and hot alkalis make up the chemical environment (see ASTM C1160: *Standard Specification for Chemical-Resistant Carbon Brick).*

The specifications regarding tile, however, cannot be assumed to be the same as brick. The physical and chemical requirements of tile are listed in ASTM C126: *Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units*. Several grades and types of tile may suit the contractor's needs. Tile is usually never thicker than three-quarters of an inch, whereas brick is greater than three-quarters of an inch. Tile is installed over a setting-bed and then grouted into place where the setting-bed and grout do not have to be the same material and usually are not. When brick is being used, however, the setting bed and grout are usually always the same material.

Furthermore, when using brick, a membrane material is first applied directly over the floor before the setting bed to ensure better chemical resistance. There commonly is no membrane under the setting-bed when applying tile due to the decreased load bearing ability of tile as compared to brick. There are also several different types of setting-beds, grouts, and mortars one can use that include furan resins, asphaltic membranes, epoxies, vinyl esters, and even inorganic silicate based cements. Again, the chemical environment as well as the intended use and application all play a part in choosing a material.

Polymer Concretes

Polymer concretes can be formulated with inorganic ceramic-based poly-

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Rehabbing an Unloading Area for a Petrochem Plant

Along the Gulf of Mexico, a Fortune 500 petrochemical facility processes extremely aggressive chemicals in an effort to maximize profits and minimize environmental impact. The truck unloading area where the raw materials are received was in very poor condition, as evidenced by a degraded coating and the chemically attacked concrete beneath it. This dilapidation created a dangerous situation because forklifts and other vehicular traffic would pass over the potholes in the slab several times throughout the day.

To provide a remedy, plant and environmental compliance engineers met to devise a procedure for rehabilitating the chemical unloading slab. A list was prepared, with each chemical cataloged including its storage temperature and concentration. The chemical configuration resembled a “witches brew,” but, fortunately, the blend of acids, solvents, and caustics were stored at ambient temperatures below 110 F (43 C). In addition to frequent splash and spill of chemicals, the slab is exposed to physical abuse in the form of forklift and 18-wheel truck traffic. Also, the material hoses that many of the chemicals are pumped through are frequently dropped directly on the slab. Due to the variety of chemicals used in the area, a vinyl ester polymer was chosen. Because of the unique nature of this application and the aggressive chemicals, only three manufacturers were considered and the list of qualified contractors was even shorter.

Constructing forms after surface preparation
Photos courtesy of the authors

A project-specific specification was drafted. Input from the manufacturer, contractor, and a third-party inspector were all incorporated. A pre-job site meeting was held 30 days prior to the start of the installation to finalize all project plans. At this point, a tentative project schedule was devised, which included the number of workers required each day, along with contingency plans and a defined safety protocol. A primary goal on this project was to minimize downtime. The installation began with a pressure wash, followed by cleaning with an industrial cleaner/degreaser to ensure no contaminants would be forced into the slab during the abrasive blasting operation. The floor slab was blasted using an aluminum oxide aggregate to aggressively prepare the surface. A cementitious concrete repair material was chosen to fill in several large depressions (>3 inches deep) in the concrete slab. Fortunately, petrographic analysis was conducted and the results, although not perfect, were very promising overall. The petrographic analysis revealed inherit weakness not visible to the eye. Each crack and joint was routed out with an electric chipping gun and filled with a flexible, chemical-resistant joint filler.

Finished flooring project

Once the cracks and joints were properly addressed, refractory anchors were set into the prepared concrete on 12-inch centerlines. The purpose of the anchors is to help secure the chemical-resistant castable polymer overlay to the substrate. The entire slab area was then formed up into 12 ft x 12 ft sections. Each section would receive a 1.5-inch thickness of a wet-applied polymer overlay. Figure 1 illustrates the surface preparation and forming. Between the slabs, a chemical-resistant expansion joint material would be applied.

The vinyl ester polymer was installed next. A resin and hardener were pre-mixed, then transferred into a mortar mixer, where a select blend of aggregates were added and mixed until a uniform consistency was achieved. The mixed material was poured into the forms, then screed and finished with steel trowels. These materials handle very similarly to Portland cement concrete mixes, but do not require a protective coating.

Before pouring the slab, workers used the same polymer material to pour in place a sump, which collects all spills. The sump hardened in two hours and the contractor proceeded to pour the slab. Thus far, after three years, no problems, failures, cracks, or deteriorations have been reported.

Table 1: Relative Comparison of General Properties of Various Flooring Types*

	CHEMICAL RESISTANCE				PHYSICAL PROPERTIES				
	Acids		Caustics	Solvents	Abrasion resistance	Compressive strength	Flexural strength	Longevity	Cost
FLOORING TYPE	**Organic**	**Inorganic**							
Portland-Based Cement	F	F	C	C	B	B	D	C	$
Bisphenol A Epoxy	C-A	C-A	A	C	A - C	A-C	B	B	$$
Bisphenol F Epoxy	B-A	B-A	A	B	A-C	A-C	B	B	$$
Novolac Epoxy	A	A	A	A	A-C	A-C	B	B	$$$
Bisphenol A Vinyl Ester	C-A	C-A	B	B	A-C	A-C	B	B	$$$
Novolac Vinyl Ester	A	B	B	A	A-C	A-C	C	A	$$$$
Polymer Concrete	A	A	A-B	A	A	A	B	A	$$$
Brick	A	A	B	A	A	A	B	A	$$$$

*** Key** **A** – Best **B** – Better **C** – Good **D** – Marginal **F** – Not Recommended $$$$ - Most Expensive $$$ - $$ - $ - Least Expensive
This rating system is relative and not intended to be quantitative.

mers, such as potassium silicate, or from organic resins, such as epoxies, vinyl esters, polyesters, and even furans. These products offer several advantages over masonry linings and coatings. Installation of polymer concretes is similar to Portland cements and, therefore, polymer concretes are faster and easier to install than masonry linings. Polymer concretes offer equal or even superior physical properties and service lives compared to masonry. The chemical resistance of polymers is equivalent to or better than masonry and their permeance is extremely low. Due to their mass and composition, polymer concretes are far more durable then coatings and linings. Using polymer concretes, usually at one-third to one-half of the thickness required for Portland concrete, eliminates the need to line or coat concrete in order to protect it, so

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there is no subsequent need for shutdowns for re-lining floors, waste disposal, or downtime costs. Without being coated, the polymer concrete can have a service life of 20 or more years. Two possible concerns with polymer concretes are the cost per cubic foot and the weight per cubic foot.

Table 1 on p. 42 gives a relative and broad comparison of the properties, performance, and costs of the representative systems from the types discussed above. The purpose of this table is to provide a broad overview of generic types. Multiple factors need to be examined before to making a recommendation.

Summary

Applying a chemically resistant floor coating over concrete can be a complicated project. It requires attention to detail in the following five key steps outlined in this paper.

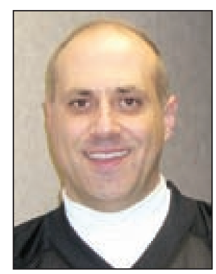
- Pre-project inspections
- Specification development
- Coating selection process
- Applicator selection process
- Establishment of and adherence to an appropriate QC/QA program

The design engineer has many options open to him or her in regards to a flooring system. He should make that choice in consultation with the coating manufacturer. Some systems will be inappropriate selections for one reason or another. The manufacturer can help sort through the various alternatives and help make a final coating selection.

When choosing a flooring system, there are several crucial elements that must be factored into the decision making process. Cost is simply not the only issue that one can use when deciding what is the most economical and beneficial flooring system for the facility owner. Factors such as the degree of substrate degradation, surface preparation, everyday mechanical stresses imposed on the floor, chemical attack, and contractor competency play an ever-increasing role in proper specification writing.

Choosing a trained and qualified contractor is also critical to the project's success. A poorly trained or unqualified applicator can result in problems all along the process and jeopardize the project's chance of success. A poorly written specification can ensure failure. The QC/QA process must be in place and fully operative before the project begins and it must be adhered to and enforced.

With a precise specification calling for proper preparation, testing, and flooring material, all parties involved in the flooring coating job will walk away knowing another long-lasting and quality floor was installed.



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Recommended Standards

- ASTM D4541, “Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers”
- ASTM C579, “Standard Test Method for Compressive Strength of Chemical-Resistant Mortar, Grouts, Monolithic Surfacings, and Polymer Concretes”
- ASTM C307, “Standard Test Method for Tensile Strength of Chemical-Resistant Mortar, Grouts, and Monolithic Surfacings”
- ASTM C580, “Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings and Polymer Concretes”
- ASTM D2240, “Standard Test Method for Rubber Property—Durometer Hardness”
- ASTM D4060, “Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser”
- ASTM D2047, “Standard Test Method for Static Coefficient of Friction of Polish-Coated Flooring Surfaces as Measured by the James Machine”
- ASTM D635, “Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position”
- ASTM D 4263, “Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method”
- ASTM D4261, “Standard Practice for Surface Cleaning Concrete Unit Masonry for Coating”
- ASTM C279, “Standard Specification for Chemical-Resistant Masonry Units”
- ASTM C1160, “Standard Specification for Chemical-Resistant Carbon Brick”
- ASTM C126, “Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units”
- SSPC-SP 12/NACE No. 5, “Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating” (*although designed for steel, it is very informative for concrete applications)
- International Concrete Repair Institute (ICRI) No. 03732, “Guideline for Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays”
- International Concrete Repair Institute (ICRI) No. 03730, “Guideline for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion”

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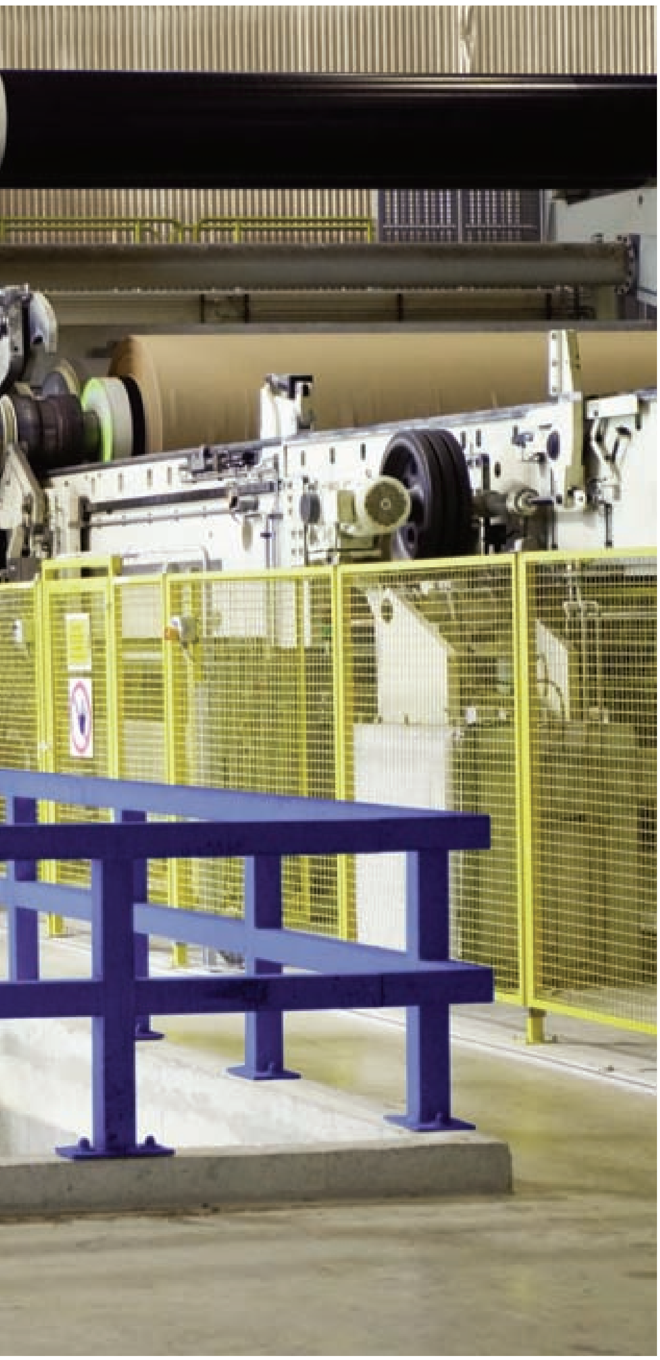


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